Tokamak KTM Progress Activity for Preparation on First Plasma Start-up

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Abstract. The activities are carried out in the Republic of Kazakhstan on creation of experimental complex on the basis of spherical tokamak KTM. The complex is meant for study of structural materials and components of future fusion reactors. At present, the following works have been completed: vacuum chamber was placed at the tokamak support; the vacuum chamber's components (excluding graphite tiles) were mounted, namely, movable divertor device (MDD), passive stabilization coils, transport-sluice device (TSD), and equatorial nozzle plugs. The electromagnetic system has been mounted: poloidal and toroidal coils were mounted at proper places and fastened; central solenoid and central column were mounted. Power structure has been mounted; system for control of vacuum chamber temperature was mounted and preliminary adjusted. Mounting, adjustment and preliminary pumping of vacuum system was completed, vacuum of 10^{-6} torr was reached without preliminary annealing of vacuum chamber and installation of graphite tiles. Partial mounting of water cooling system and pulse power supply system for the electromagnetic system of tokamak KTM was carried out. The diagnostics of first order of the tokamak KTM were adjusted. After completion of mounting of all the systems, start-up activities for all the systems will be carried out. Trial start of tokamak KTM with realization of disruption stage was realized on September 5, 2010. Physical start-up of tokamak KTM will be carried out in 2011.

1. Introduction

Tokamak KTM is created in Republic of Kazakhstan, Kurchatov, East-Kazakhstan region. Experimental complex on the basis of spherical tokamak KTM is intended to study and test first wall materials and designs of divertor plates of reactor-tokamaks, to try out the methods to reduce the loads at a divertor and various methods of heat and energy removal, as well as the methods of fast exhaust of divertor volume and development of the methods to prevent unscheduled failures of intrachamber components. Mix of hydrogen and deuterium was selected as a working gas of the tokamak. Coils of electromagnetic system (EMS) of the tokamak KTM is cooled by water (warm windings). Main stream power of the plasma is directed into divertor area at the receiving tiles. The main parameters of the tokamak KTM is given in Table I.

Table I. Parameter of Tokamak KTM

Plasma major radius	0.9 m
Plasma minor radius	0.45 m
Aspect ratio, A	2.0
Plasma elongation, K95	1.7
Toroidal magnetic field, Bto	1.0 T
Plasma current	0.75 MA
Duration of current plateau	4 – 5 s
Additional RF-heating power	5 MW
Thermal load on the divertor tiles	2 –20 MW/m^2

2. Main Features and Goals of Tokamak KTM

Tokamak KTM has a feature for operative access into vacuum chamber for replacement of divertor elements without loss of high vacuum.

Parameters of the power loads, wide range of the techniques and diagnostics (physical and technological) will allow for the studies and tests of various divertors under given modes at a divertor and first wall, which will contribute the studies of the plasma-facing materials in the ITER and DEMO programs, as well as for other experimental/power fusion reactors [1-5].

The goals of tokamak KTM is as follows:

- Creation of unique research base for development of the materials and related technologies of the fusion reactors, as well as units and components of reactor chambers;
- Study of principal plasma-physical characteristics of compact tokamaks as a fusion component of the hybrid reactors for recovery of artificial nuclear fuel, processing of long-lived high level radioactive wastes of nuclear industry, and, possibly, for production of electric power in sub-critical systems;

- Work-out of high resource designs of the divertors and first wall, study of the modes of RF-heating and non-induction current generation for the benefit of ITER and DEMO;

- Organization of an international laboratory as a center of international cooperation with Russian Federation, EU, US, Japan, China and South Korea and nomination of “KTM Users’ Club”.

3. Main Activities for Preparation on First Plasma Start-up

At present, the following activities were completed at tokamak KTM:

1. Vacuum chamber was placed at the tokamak support; vacuum chamber’s components except the tiles were mounted, including passive stabilization coils, transport-sluice device (TSD), and equatorial nozzle plugs.

2. The electromagnetic system has been mounted: poloidal coils were mounted at proper places and fastened; toroidal field coils were mounted at their working places and high-current contact connections were realized between central column and toroidal coils; central solenoid and central column were mounted; gaps were set between central solenoid and central column;

3. Power structure has been mounted: power structure columns were mounted at their designated places – tokamak support, power structure brackets were mounted jointly with the power structure columns;

4. Adjustment of vacuum chamber position relative to central column was carried out;

5. Mounting, adjustment and preliminary pumping of the vacuum system (see FIG. 1) was completed, vacuum of 10^{-6} torr was reached without preliminary annealing of vacuum chamber and installation of graphite tiles;

FIG. 1. Pumping of KTM vacuum chamber

6. Mounting and preliminary adjustment was carried out for the temperature control system of the vacuum chamber;

7. Partial mounting of water cooling system and EMS pulse power supply system of tokamak KTM was carried out;

8. There were manufactured, delivered and mounted at the designated places the poles of plasma control system, the poles for digital control of EMS KTM power sources, poles for synchronization and emergency protection system;

9. The activities on manufacturing, further mounting and adjustment of the following systems are in progress now: water cooling system, vacuum pumping system (TSD, RF-antennas, RF-system feeders, physical diagnostics), RF-generators; RF-generator power sources; EMS KTM power sources; automatic control system, including development of software for all the subsystems, system for vacuum chamber conditioning by plasma discharge;

10. Assembling and mounting of KTM control panel (FIG. 2) were completed;

FIG. 2. KTM control panel

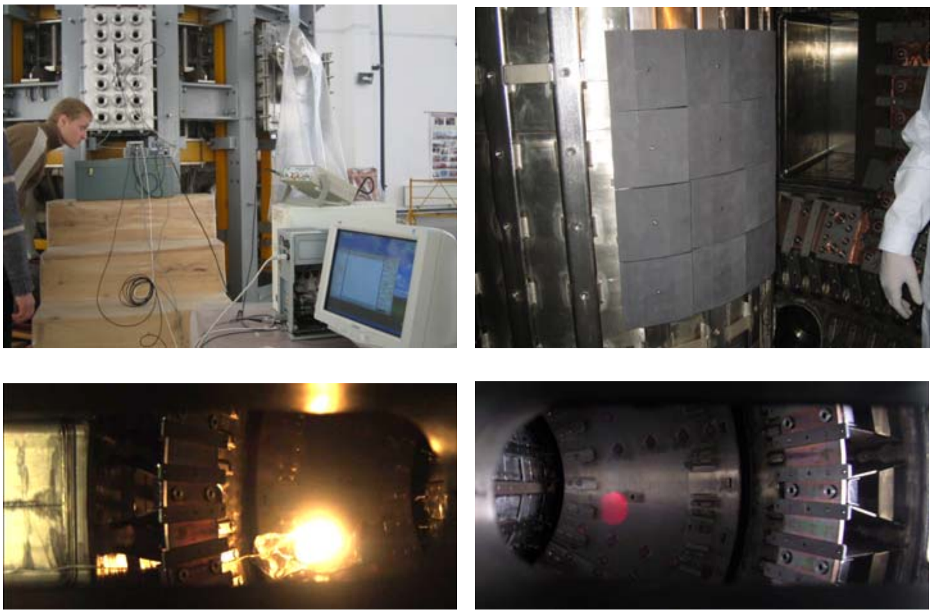

FIG.3. Adjustment of physical diagnostics at tokamak KTM

11. Preparations for mounting of all the systems of physical diagnostics and their adjustment under real conditions were completed. Working-out of the techniques for adjustment of first order diagnostics at tokamak KTM (FIG. 3) and the techniques for tokamak KTM start-up was completed. In particular, the following diagnostics were adjusted: RF interferometer for measurement of average density of plasma in discharge cross section, f=170 GHz; two-frequency pulse radar-reflectometer, f=19; 22 GHz, for measurement of density gradient of plasma in discharge cross section; multichannel monitor for study of the lines of isotopes of hydrogen Hα-Dα to determine plasma heterogeneousness structure (FIG. 4), integrated bolometer and multichannel monitor of a structure of power losses to define radiation losses of plasma, video camera of standard picture frequency and frequency up to 1000 Hz – JAI CB-140GE, fastec Inline 1000 Color 512 Mb.

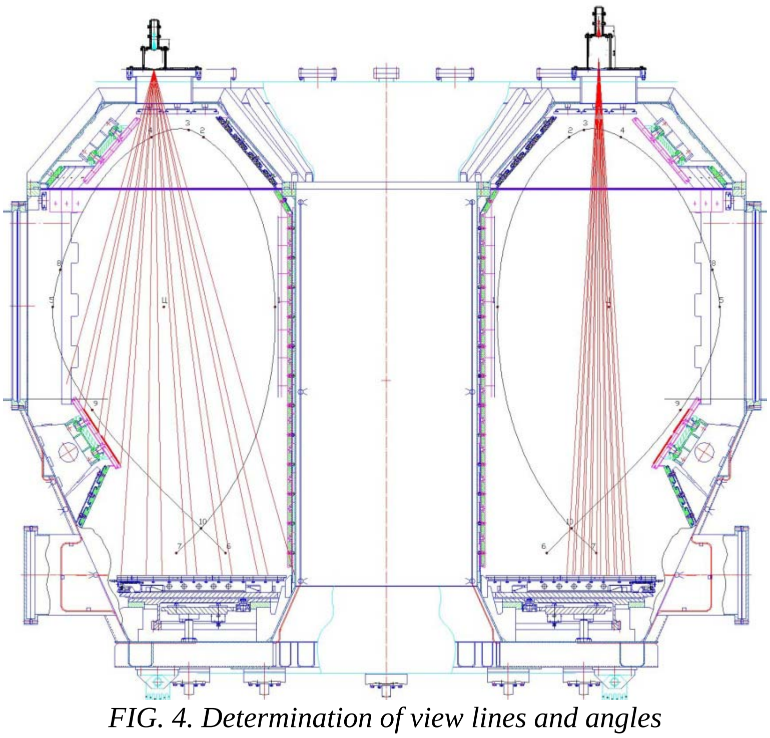

FIG. 4. Determination of view lines and angles

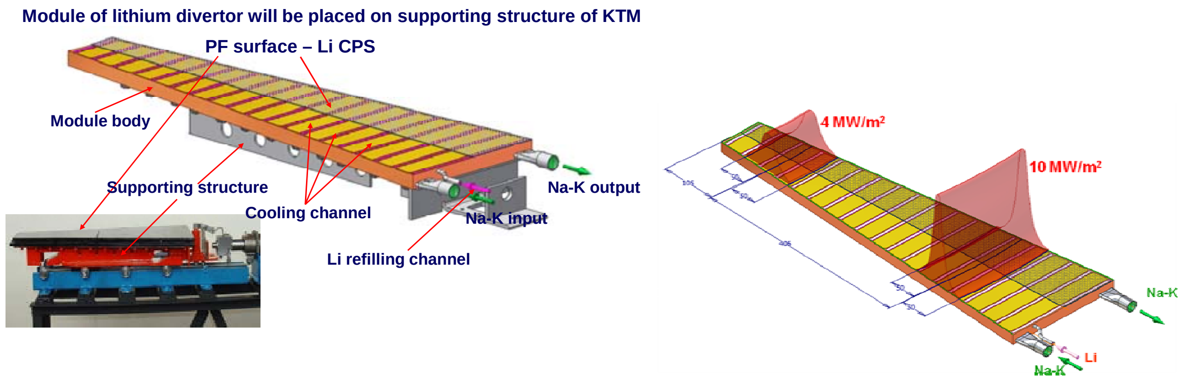

FIG. 5. Module of lithium divertor and distribution of heat load along the surface if the lithium divertor module (calculation)

After completion of mounting of all the systems, the start-up activities for all the systems will be carried out, including heating system of vacuum chamber with ohmic and induction heaters with water cooling of central solenoid and central column, trials of all the power sources with maximal currents with loading own coils, working-out of the diagnostics jointly with registration and synchronization system.

In the framework of KTM project realization we start the development and justification of demonstration models of lithium divertor of tokamak KTM. Work is carried out jointly with Russian organizations: Krasnaya Zvezda (Red Star) and TRINITI under the ISTC project K-1561 with EU financing. As a result of the project realization the cooling module of lithium divertor for tokamak KTM will be designed and tested. The module (FIG. 5) with renewed lithium surface will be able to operate under specific heat loads from 2 to 10 MWt/m^2, with duration of quasi-stationary mode up to ~5 sec.

At first stage, total power released from discharge under quasi-stationary mode will be about 1 MW. In the framework of the Project the technology will be developed and tested to assemble and mount lithium modules in the tokamak, allowing for replacement of divertor components. After first tests and revision of the module design the issue of creation of full-scale lithium divertor for tokamak KTM will be considered, total released power will be about 5 MW.

4. KTM Trial Start-up

Trial start of tokamak KTM with realization of disruption stage was done in September 5, 2010. The goal of this trial start-up was to reach breakdown of working gas in the KTM's vacuum chamber and to form plasma column with 10-30 mA current.

The following systems (FIG. 6) were used to reach the goal: pre-ionization system for ionization of working gas, power source of electromagnetic winding of toroidal field, capacitor power source of central solenoid and electromagnetic windings of poloidal field PF1, PF4, magnetic diagnostics, video camera and photoelectron multiplier (PEM) for physical parameters' diagnosis.

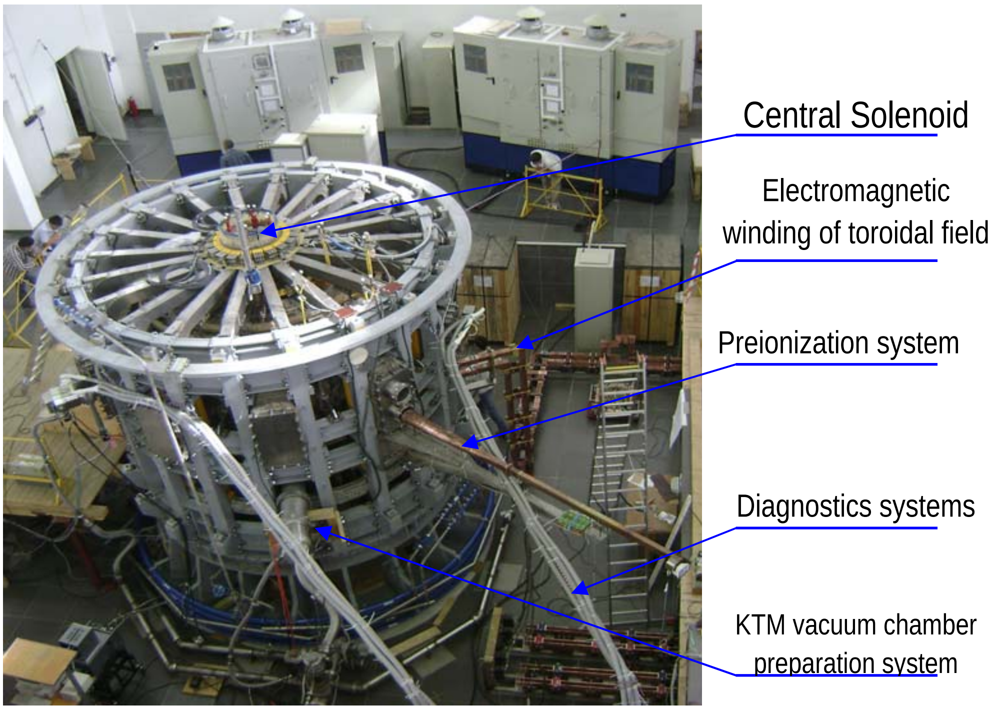

FIG. 6. Systems of the Tokamak KTM used during start-up

The video camera snapshot on 20 ms from the beginning of current input on central solenoid from the side of vertical branch pipe during the plasma discharge duration is shown in FIG. 7. The diagram of plasma current during KTM trial start-up is shown in FIG. 8.

5. Conclusions

Realization of trial start-up of the tokamak KTM with additional power source (capacitor battery) and pre-ionization system allowed for generation of plasma discharge of max current of 25 kA and plasma discharge duration of t=40 ms; that is in correspondence with calculation scenarios.

Mounting of the main KTM systems are realized in accordance with the schedule. Physical start-up of tokamak KTM is planned in 2011 and start of operation - 2012/2013.

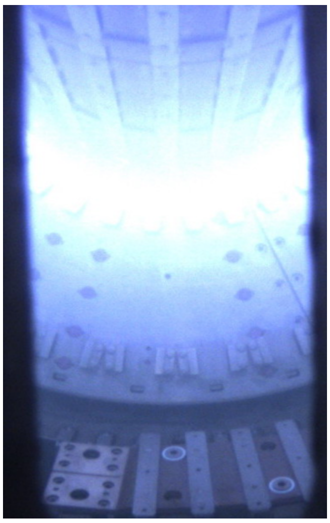

FIG. 7. Tokamak KTM first plasma

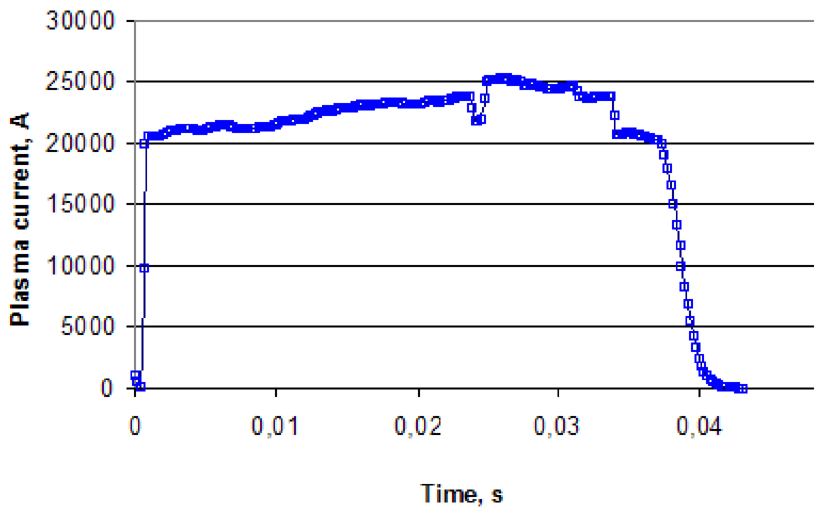

FIG. 8. The diagram of plasma current during KTM trial start-up

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